A Quantitative Analysis of Subsidy Competition in the U.S.

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April 2015

Motivation and objectives

- Motivation
  - US cities, counties, and states spend substantial resources on subsidies trying to attract firms from other locations
  - The annual costs of such subsidies range from \$33.4m in Nevada to \$19.1bn in Texas and total \$80.4bn nationwide
- Objectives
  - Understand what motivates regional governments to subsidize firm relocations and quantify how strong their incentives are
  - Characterize fully non-cooperative and cooperative subsidy choices and assess how far away we are from these extremes

Approach and findings

- Approach
  - I pursue these objectives in the context of a quantitative economic geography model which I calibrate to US states
  - I calculate optimal subsides, Nash subsidies, and cooperative subsidies and compare them to observed subsidies
- Findings
  - I show that states have strong incentives to subsidize firm relocations in order to gain at the expense of other states
  - Observed subsidies are closer to cooperative than non-cooperative subsidies but the potential losses from an escalation of subsidy competition are large

Key model features

- In my model, the location of economic activity is determined by a combination of first and second advantages
- It emphasizes agglomeration forces in the New Economic Geography tradition but is isomorphic to one with external IRS
- It can be calibrated to the US economy using data on internal trade flows, subsidies, and the distribution of workers alone
- I make many simplifications in the interest of transparency so that my numbers have to be interpreted with a grain of salt

Contribution

- I am not aware of any comparable analysis of noncooperative and cooperative policy in a spatial environment
- Theoretical work such as Baldwin et al (2005) restricts attention to highly stylized models whereas I connect to data
- Quantitative work such as Gaubert (2014) and Serrato and Zidar (2014) takes policy as given whereas I endogenize it
- Methodologically most similar are the recent contributions by Ossa (2014), Redding (2014), and Caliendo et al (2014)
- My modeling of agglomeration forces builds on Krugman (1991), Krugman and Venables (1995), and Allen and Arkolakis (2014)

Outline

- Framework
- Calibration
- Analysis

- Preferences are common over goods and heterogeneous over amenities:

$$
\begin{aligned}
U_{jv} &= U_j \exp\left(a_{jv}\right) \\
U_j &= A_j \frac{C_j^F}{L_j} \\
C_j^F &= \left(\sum_i \int_0^{M_i} c_{ij}^F \left(\omega_i\right)^{\frac{\varepsilon-1}{\varepsilon}} d\omega_i \right)^{\frac{\varepsilon}{\varepsilon-1}} \\
a_{jv} &\sim Gumbel\left(0, \sigma\right)
\end{aligned}
$$

Setup - Technology

- Firms use labor, capital, and intermediate goods:

$$
\begin{aligned}
q_j &= \varphi_j \left(i_j - f_j \right) \\
i_j &= \frac{1}{M_j} \left(\frac{1}{\eta} \left(\frac{L_j}{\theta^L} \right)^{\theta^L} \left(\frac{K_j}{\theta^K} \right)^{\theta^K} \right)^{\eta} \left(\frac{C_j^I}{1-\eta} \right)^{1-\eta} \\
C_j^I &= \left(\sum_i \int_0^{M_i} c_{ij}^I \left(\omega_i \right)^{\frac{\varepsilon-1}{\varepsilon}} d\omega_i \right)^{\frac{\varepsilon}{\varepsilon-1}} \\
1 &= \theta^L + \theta^K
\end{aligned}
$$

Setup - Government

- I adopt a simple formulation of subsidy policy to allow for a transparent analysis
- Governments are assumed to maximize the common component of worker utility
- Subsidies are given to all local firms to pay for a fraction of their overall costs
- These local cost subsidies are financed with local lump-sum taxes on consumers

$$E_i^F = w_i L_i + \lambda_i^L r K - s_i \left(w_i L_i + r K_i + E_i^I \right) - \Omega_i$$

Short

Equilibrium - Solution

- For given subsidies, consumers maximize utility, firms maximize profits, firms make zero profits, and markets clear
- The solution of the model can be expressed as a system of $3R$ equilibrium conditions in the $3R$ unknowns $\lambda_i^L, \lambda_i^K, P_i$
- However, this system depends on a large number of parameters which are hard to estimate including $\tau_{ij}, \varphi_i, f_i, A_i$
- I circumvent this difficulty by expressing the equilibrium conditions in changes using "exact hat algebra" techniques
- I only need T_{ij}, λ_i^L, s_i and $\theta^L, \theta^K, \eta, \varepsilon, \sigma$ and compute counterfactuals from a benchmark which matches T_{ij}, λ_i^L, s_i

Conditions

Equilibrium - Exact hat algebra

Proof.

$$P_j = \left(\sum_i M_i \left(p_i \tau_{ij} \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$$

$$\frac{P_j'}{P_j} = \left(\sum_i \frac{M_i \left(p_i \tau_{ij} \right)^{1-\varepsilon} \left(P_j \right)^{\varepsilon-1} E_j}{\sum_m M_m \left(p_m \tau_{mj} \right)^{1-\varepsilon} \left(P_j \right)^{\varepsilon-1} E_j} \frac{M_i'}{M_i} \left(\frac{p_i'}{p_i} \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$$

$$T_{ij} = M_i \left(p_i \tau_{ij} \right)^{1-\varepsilon} \left(P_j \right)^{\varepsilon-1} E_j$$

$$\hat{P}_j = \left(\sum_i \frac{T_{ij}}{\sum_m T_{mj}} \hat{M}_i \left(\hat{p}_i \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$$

$\square$

Equilibrium - Isomorphism

- Agglomeration forces: Consumers want to be close to firms and firms want to be close to firms to take advantage of lower prices
- Dispersion forces: Consumers have heterogeneous preferences over locations but there are no local fixed factors such as housing
- The model is isomorphic to an Armington model with external IRS technology up to the scale of φ_i if $\phi = \frac{1}{\varepsilon - 1}$ and technology is

$$
\begin{aligned}
q_i &= \varphi_i \left(I_i\right)^{1+\phi} \\
I_i &= \left(\frac{1}{\eta}\left(\frac{L_i}{\theta^L}\right)^{\theta^L}\left(\frac{K_i}{\theta^K}\right)^{\theta^K}\right)^{\eta}\left(\frac{C_i^I}{1-\eta}\right)^{1-\eta}
\end{aligned}
$$

Data - Sources

- 2007 Commodity Flow Survey
  - T_{ij} ▸ Map
- New York Times Business Incentives Database
  - $\bar{s}_i = 0.7\%$, $s_i^{min} = 0.0\%$ (NV), $s_i^{max} = 5.4\%$ (VT) ▸ Map
- 2007 Bureau of Economic Analysis Input-Output Table
  - $\theta^L = 0.57$, $\theta^K = 0.43$, $\eta = 0.58$
- 2007 Annual Survey of Manufacturing
  - λ_i^L ▸ Map
- Oberfield and Raval (2014)
  - $\varepsilon = 4$
- Equilibrium conditions
  - λ_i^K, Ω_i ▸ Details

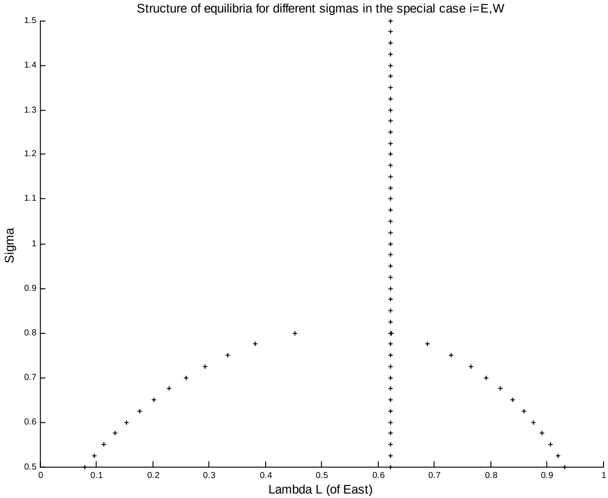
- I purge the trade data of the net exports due to transfers in order to avoid having to take a stance on the units in which they are held fixed

- For this calculation, I work with a version of the model without labor mobility so that all adjustments come from wage changes and capital flows Details

- I also introduce a federal subsidy on intermediate purchases in order to be able to focus on the beggar-thy-neighbor aspects of state subsidies Details

$$p_{ij} = \frac{\varepsilon}{\varepsilon - 1} \frac{\left((w_i)^{\theta^L} (r)^{\theta^K} \right)^{\eta} \left(\rho^I P_i \right)^{1-\eta} \rho_i \tau_{ij}}{\varphi_i}$$

East and West - Multiplicity of equilibria

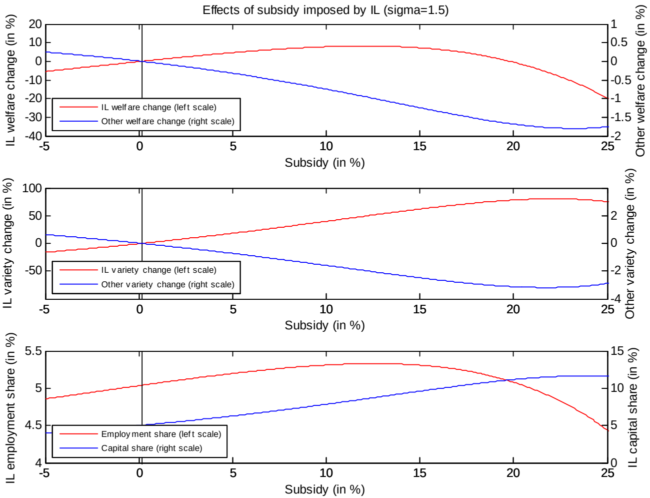


Stability

Full sample - Assuming uniqueness and stability

- I choose $\sigma \geq 1.5$ to make sure that the factual equilibrium is unique and stable ▸ Example
- I determine this threshold by trying out a large number of random guesses and subsidy shocks
- The lower σ, the more equilibria appear, involving extreme agglomeration in reasonable states
- I do not attempt to estimate σ but consider various values capturing different time horizons
- Serrato and Zidar (2014) estimate $\sigma = 0.7$ but also include housing as another dispersion force

Welfare effects of subsidy - Example



Welfare effects of subsidy - Decomposition

- Under certain restrictions, the welfare effects resulting from small subsidy changes can be decomposed into:

$$\frac{dU_j}{U_j} = \underbrace{\frac{1}{\eta}\frac{1}{\varepsilon - 1}\sum_i \frac{T_{ij}}{E_j}\frac{dM_i}{M_i}}_{\text{home market effect}} + \underbrace{\frac{1}{\eta}\sum_i \frac{T_{ij}}{E_j}\left(\frac{dp_j}{p_j} - \frac{dp_i}{p_i}\right)}_{\text{terms-of-trade effect}}$$

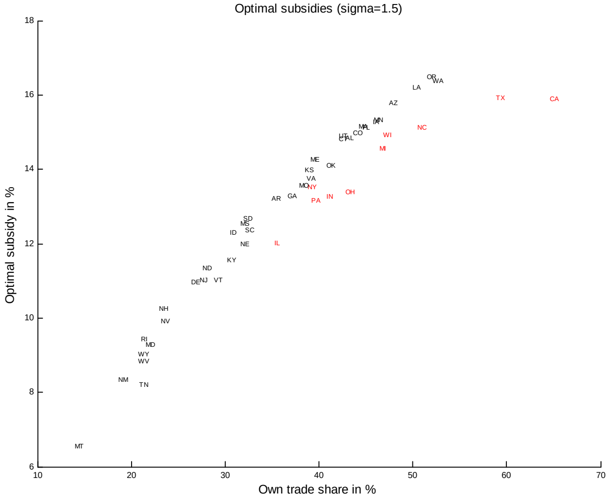
- Moreover, price changes depend on subsidy changes, wage changes, and price index changes so that:

$$\frac{dToT_j}{ToT_j} = \underbrace{\theta^L \sum_{i=1}^{R} \frac{T_{ij}}{E_j}\left(\frac{dw_j}{w_j} - \frac{dw_i}{w_i}\right)}_{\text{relative wage effect}} + \underbrace{\frac{1}{\eta}\sum_{i=1}^{R} \frac{T_{ij}}{E_j}\left(\frac{d\rho_j}{\rho_j} - \frac{d\rho_i}{\rho_i}\right)}_{\text{direct subsidy effect}} + \underbrace{\frac{1-\eta}{\eta}\sum_{i=1}^{R} \frac{T_{ij}}{E_j}\left(\frac{dP_j}{P_j} - \frac{dP_i}{P_i}\right)}_{\text{intermediate cost effect}}$$

- For example, if IL unilaterally imposes a 5 percent subsidy, the approximate welfare effects are:

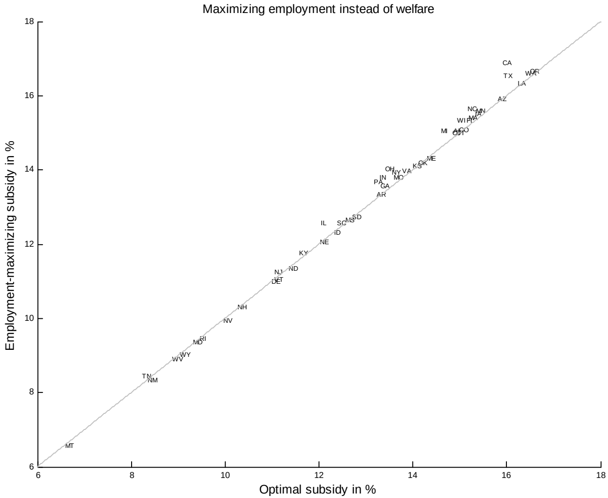
	U	HME	TOT	TOT_w	TOT_ρ	TOT_P
IL	4.7%	3.1%	1.6%	6.8%	-4.6%	-0.6%

Optimal subsidies

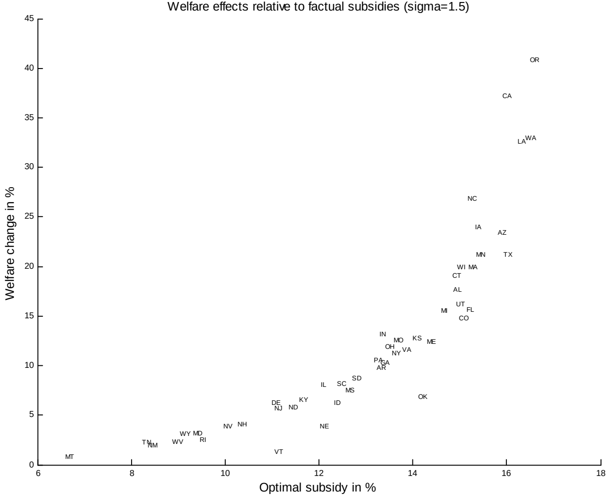


Details

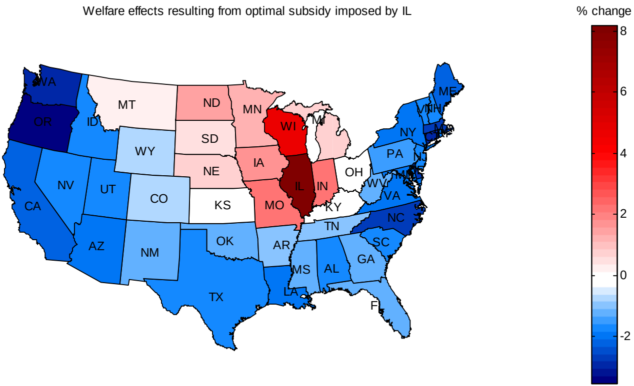
Optimal subsidies - Maximizing employment



Optimal subsidies - Welfare effects



Optimal subsidies IL - Geography of welfare effects



Factor flows

Optimal subsidies - Sensitivity

Sensitivity wrt ε

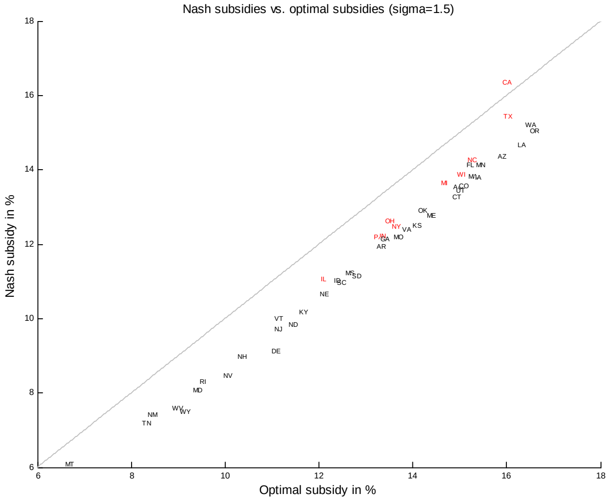
ε	s	ΔU		$\Delta\lambda^L$
	avg.	own	other	avg.
4.0	13.0%	12.9%	-0.8%	8.6%
4.5	11.0%	6.2%	-0.4%	4.2%
5.0	9.6%	3.8%	-0.2%	2.6%
5.5	8.6%	2.6%	-0.1%	1.8%
6.0	7.7%	1.9%	-0.1%	1.3%
6.5	7.1%	1.4%	-0.1%	1.0%

Sensitivity wrt σ

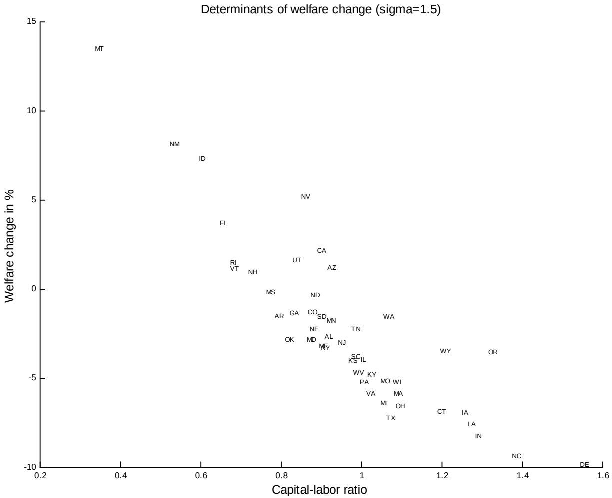
σ	s	ΔU		$\Delta\lambda^L$
	avg.	own	other	avg.
1.5	13.0%	12.9%	-0.8%	8.6%
3.0	12.6%	8.3%	-0.5%	2.8%
4.5	12.5%	7.5%	-0.5%	1.7%
6.0	12.4%	7.1%	-0.4%	1.2%
7.5	12.4%	6.9%	-0.4%	0.9%
9.0	12.4%	6.8%	-0.4%	0.8%

Short

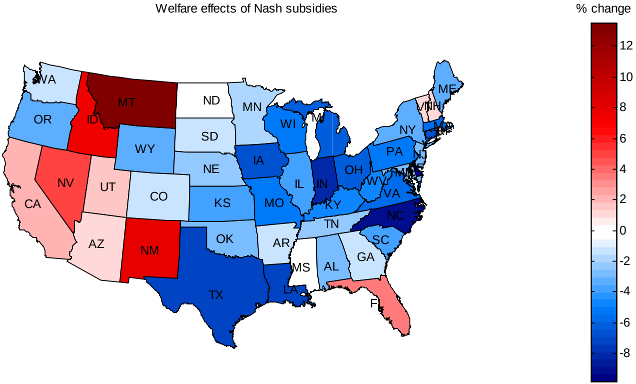
Nash subsidies



Nash subsidies - Welfare effects



Nash subsidies - Geography of welfare effects



Factor flows

Nash subsidies - Sensitivity

Sensitivity wrt ε

ε	s	ΔU	$\Delta\lambda^L$
4.0	11.8%	-2.3%	0.9%
4.5	10.3%	-1.3%	0.6%
5.0	9.1%	-0.8%	0.5%
5.5	8.2%	-0.5%	0.4%
6.0	7.5%	-0.3%	0.3%
6.5	6.9%	-0.2%	0.3%

Sensitivity wrt σ

σ	s	ΔU	$\Delta\lambda^L$
1.5	11.8%	-2.3%	0.9%
3.0	11.6%	-2.3%	0.4%
4.5	11.5%	-2.3%	0.2%
6.0	11.5%	-2.3%	0.2%
7.5	11.5%	-2.3%	0.1%
9.0	11.5%	-2.3%	0.1%

Cooperative subsidies

- Governments follow a bargaining process resembling symmetric Nash bargaining: $\max_{\{s,\Omega\}} \hat{U}_1$ s.t. $\hat{U}_1 = \hat{U}_i \; \forall \; i$ and $\sum_i \Omega_i = 0$
- Cooperative subsidies are always zero while cooperative transfers vary depending on the starting point to ensure $\hat{U}_1 = \hat{U}_i \; \forall \; i$
- Welfare increases by 3.9 percent starting at Nash subsidies and by 0.04 percent starting at factual subsidies in all states
- Cooperative subsidies would be $1/\varepsilon$ if the federal government did not subsidize intermediate consumption at a rate $1/\varepsilon$

Transfers and capital flows

Cooperative subsidies - Sensitivity

Sensitivity wrt ε

ε	s	ΔU	$\Delta\lambda^L$
4.0	0%	3.9%	0%
4.5	0%	2.4%	0%
5.0	0%	1.7%	0%
5.5	0%	1.2%	0%
6.0	0%	0.9%	0%
6.5	0%	0.7%	0%

Sensitivity wrt σ

σ	s	ΔU	$\Delta\lambda^L$
1.5	0%	3.9%	0%
3.0	0%	3.8%	0%
4.5	0%	3.7%	0%
6.0	0%	3.7%	0%
7.5	0%	3.7%	0%
9.0	0%	3.7%	0%

Starting at Nash eq.

Sensitivity wrt ε

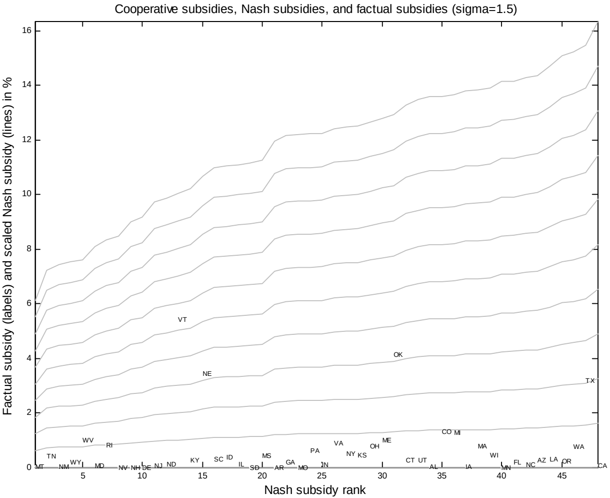
ε	s	ΔU	$\Delta\lambda^L$
4.0	0%	0.04%	0%
4.5	0%	0.04%	0%
5.0	0%	0.03%	0%
5.5	0%	0.03%	0%
6.0	0%	0.03%	0%
6.5	0%	0.03%	0%

Sensitivity wrt σ

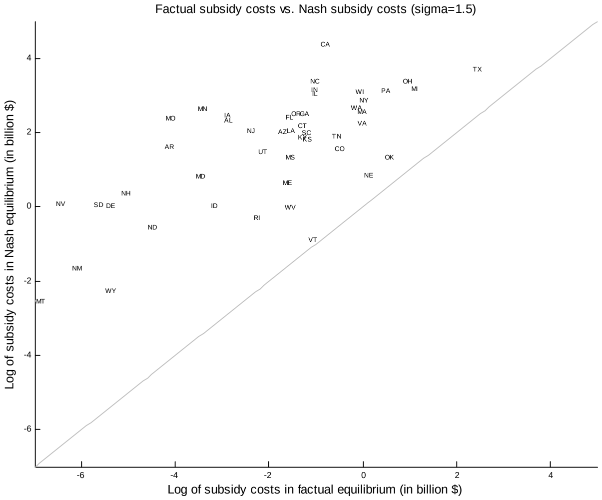
σ	s	ΔU	$\Delta\lambda^L$
1.5	0%	0.04%	0%
3.0	0%	0.04%	0%
4.5	0%	0.04%	0%
6.0	0%	0.04%	0%
7.5	0%	0.04%	0%
9.0	0%	0.04%	0%

Starting at factual eq.

Observed vs. counterfactual subsidies



Observed vs. counterfactual subsidy costs



Conclusion

- I analyze subsidy wars and subsidy talks among US states using a quantitative economic geography model
- I believe this is the first quantitative analysis of noncooperative and cooperative policy in a spatial environment
- By using "exact hat algebra" techniques I move beyond the illustrative numerical examples typical of the literature
- My results still have to be interpreted with caution since I make many simplifications in the interest of transparency

$$E_i^F = w_i L_i + \lambda_i^L rK - s_i \left(w_i L_i + rK_i + \rho^I E_i^I \right) - \lambda_i^L s^I \sum_{m=1}^{R} E_m^I - \Omega_i$$

$$\lambda_i^L = U_i^{\frac{1}{\sigma}} / \sum_{j=1}^{R} U_j^{\frac{1}{\sigma}}$$

$$U_i = A_i E_i^F / \left(L_i P_i \right)$$

$$w_i L_i = \left(\theta^L / \theta^K \right) rK_i$$

$$E_i^I = \left(\left(1 - \eta \right) / \rho^I \eta \theta^K \right) rK_i$$

$$p_i = \frac{\varepsilon}{\varepsilon - 1} \frac{\left(\left(w_i \right)^{\theta^L} \left(r \right)^{\theta^K} \right)^{\eta} \left(\rho_i^I P_i \right)^{1-\eta} \rho_i}{\varphi_i}$$

$$\frac{1}{\varepsilon} \sum_{j=1}^{R} \left(p_i \tau_{ij} \right)^{1-\varepsilon} \left(P_j \right)^{\varepsilon - 1} \left(E_j^F + E_j^I \right) = \left(\left(w_i \right)^{\theta^L} \left(r \right)^{\theta^K} \right)^{\eta} \left(\rho^I P_i \right)^{1-\eta} \rho_i f_i$$

$$M_i = \frac{L_i}{\varepsilon f_i \eta \theta^L} \frac{w_i}{\left(\left(w_i \right)^{\theta^L} \left(r \right)^{\theta^K} \right)^{\eta} \left(\rho^I P_i \right)^{1-\eta}}$$

$$P_j = \left(\sum_{i=1}^{R} M_i \left(p_i \tau_{ij} \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$$

$$\hat{E}_i^F = \frac{w_i L_i}{E_i^F}\hat{w}_i\hat{\lambda}_i^L + \frac{\lambda_i^L rK}{E_i^F}\hat{\lambda}_i^L - \frac{S_i}{E_i^F}s_i'\left(\frac{w_i L_i}{S_i}\hat{w}_i\hat{\lambda}_i^L + \frac{rK_i}{S_i}\hat{\lambda}_i^K + \frac{\rho^I E_i'^I}{S_i}\hat{E}_i^I\right) - \frac{S_i^I}{E_i^F}\hat{\lambda}_i^L\sum_{m=1}^{R}\lambda_m^K\hat{E}_m^I - \frac{\Omega_i^I}{E_i^F}$$

$$\hat{\lambda}_i^L = \left(\hat{U}_i\right)^{\frac{1}{\sigma}} / \sum_{j=1}^{R}\lambda_j^L\left(\hat{U}_j\right)^{\frac{1}{\sigma}}$$

$$\hat{U}_i = \hat{E}_i^F / \left(\hat{\lambda}_i^L\hat{P}_i\right)$$

$$\hat{w}_i\hat{\lambda}_i^L = \hat{\lambda}_i^K$$

$$\hat{E}_i^I = \hat{\lambda}_i^K$$

$$\hat{p}_i = \left(\hat{w}_i\right)^{\theta^L\eta}\left(\hat{P}_i\right)^{1-\eta}\hat{\rho}_i$$

$$\sum_{j=1}^{R}\frac{T_{ij}}{\sum_n T_{in}}\left(\hat{P}_j\right)^{\varepsilon-1}\left(\frac{E_j^F}{E_j}\hat{E}_j^F + \frac{E_j^I}{E_j}\hat{E}_j^I\right) = \left(\hat{p}_i\right)^{\varepsilon}$$

$$M_i = \frac{L_i}{\varepsilon f_i\eta\theta^L}\frac{w_i}{\left(\left(w_i\right)^{\theta^L}\left(r\right)^{\theta^K}\right)^{\eta}\left(\rho^I P_i\right)^{1-\eta}}$$

$$\hat{P}_j = \left(\sum_{i=1}^{R}\frac{T_{ij}}{\sum_m T_{mj}}\hat{M}_i\left(\hat{p}_i\right)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$$

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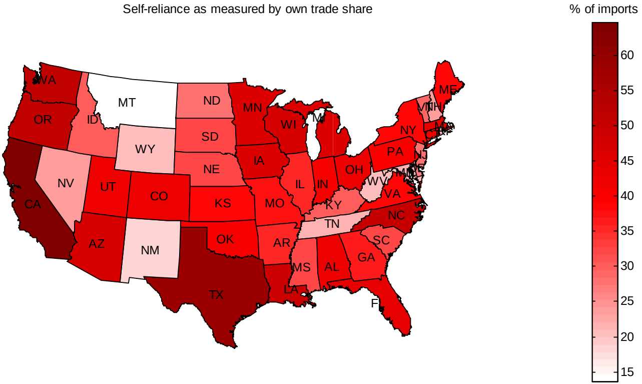
Data - Self-reliance



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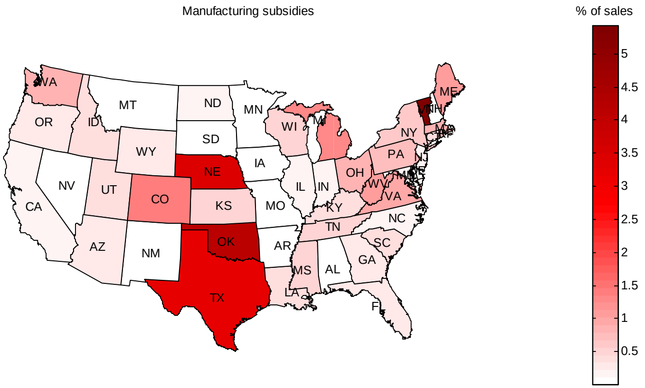
Data - Distribution of subsidies



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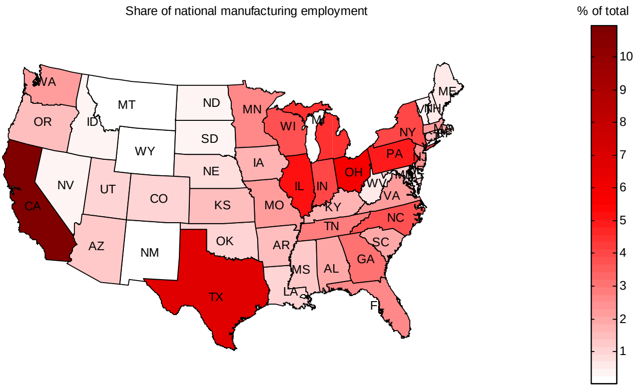
Data - Distribution of manufacturing employment



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Data - Inference

- The model links observed trade flows and unobserved capital incomes and capital shares through the following equilibrium conditions:

$$
\begin{aligned}
rK_i &= \frac{\theta^K \eta}{\rho_i} \sum_n T_{in} \\
\lambda_i^K &= \frac{rK_i}{\sum_m rK_m}
\end{aligned}
$$

- The model also allows me to decompose net exports into an endogenous component and a residual Ω_j which I interpret as transfers:

$$
\sum_n \left(T_{jn} - T_{nj} \right) = \left(\lambda_j^K - \lambda_j^L \right) rK + \Omega_j
$$

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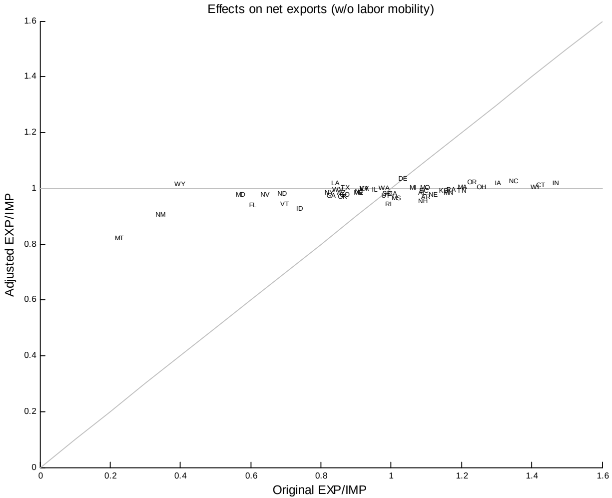
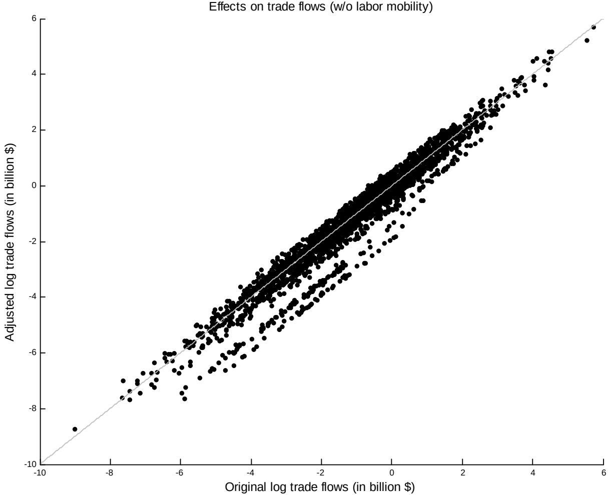
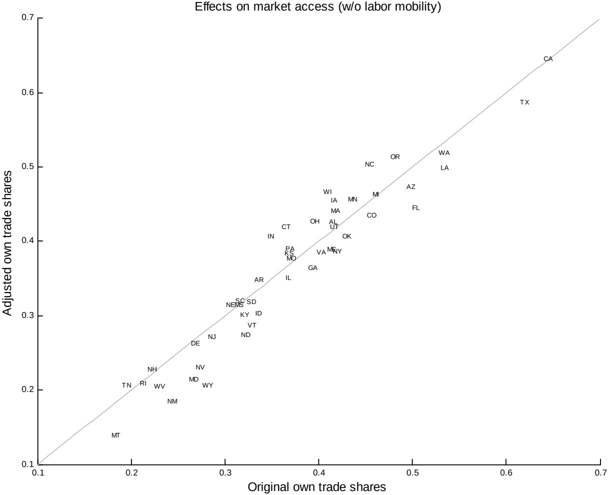
Adjustment I - Transfers



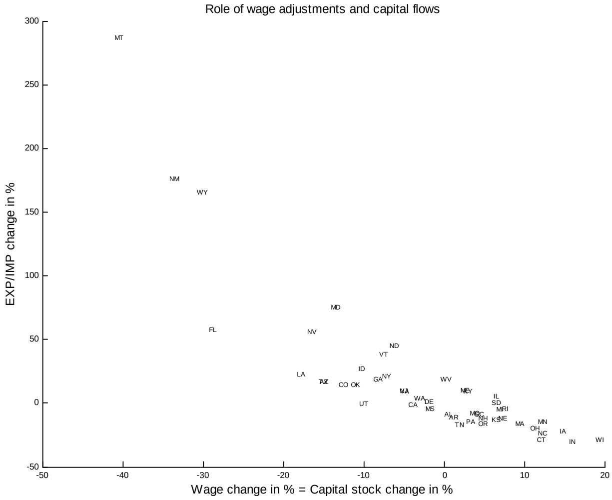
Adjustment I - Transfers



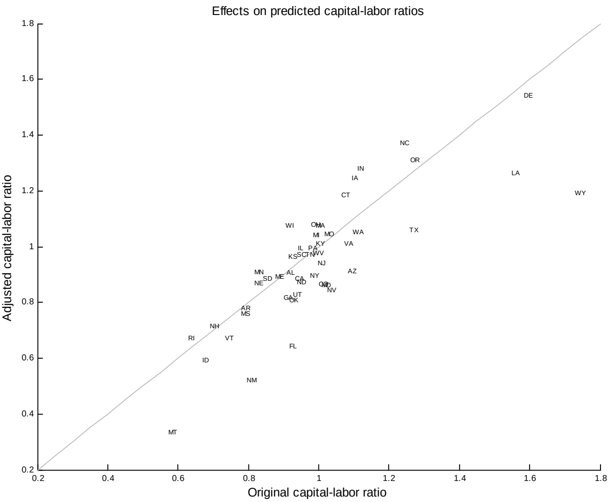
Adjustment I - Transfers



Adjustment I - Transfers



Adjustment I - Transfers



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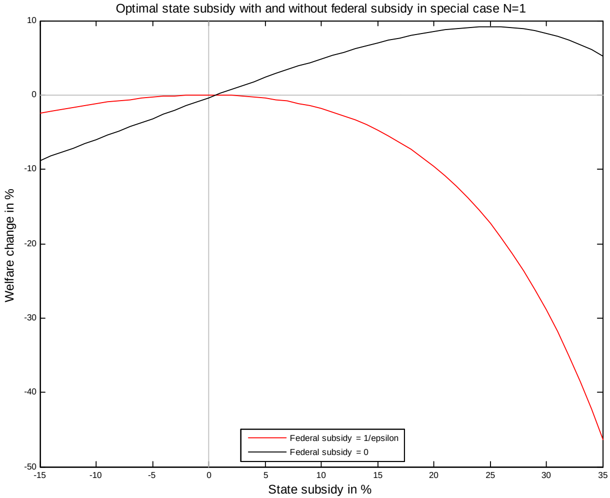
Adjustment II - Federal subsidy



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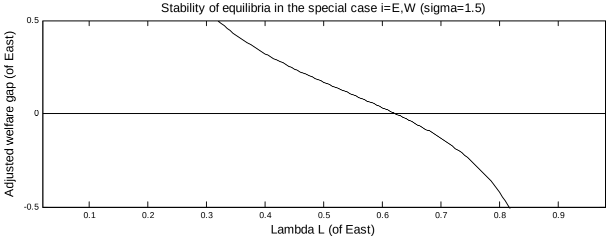
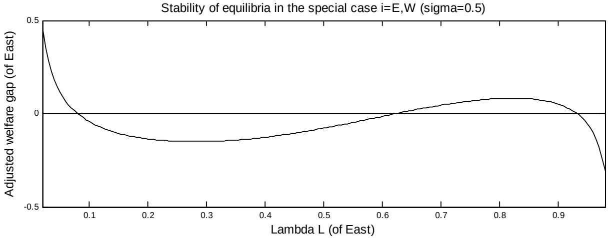
East and West - Stability of equilibria





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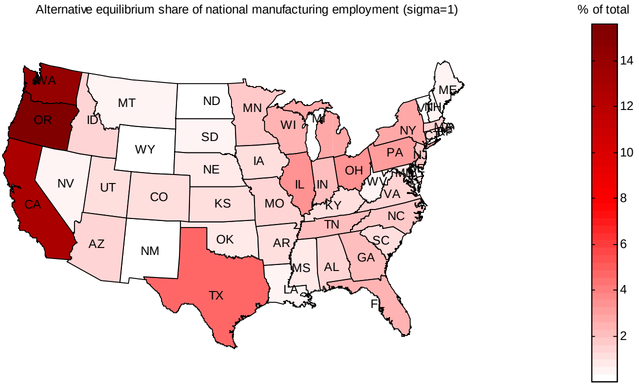
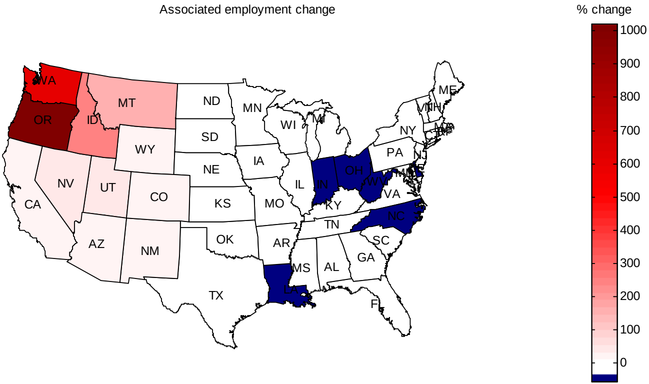
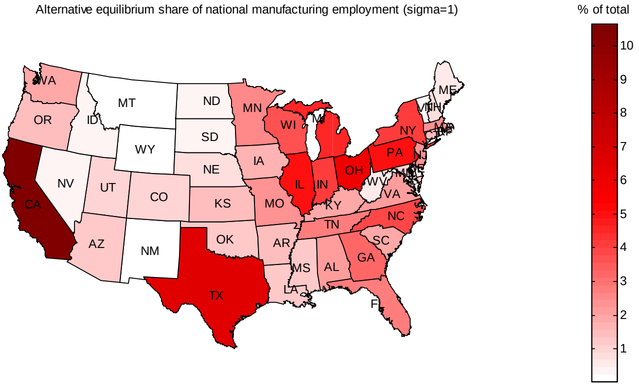
Multiplicity of equilibria - Agglomeration on West Coast



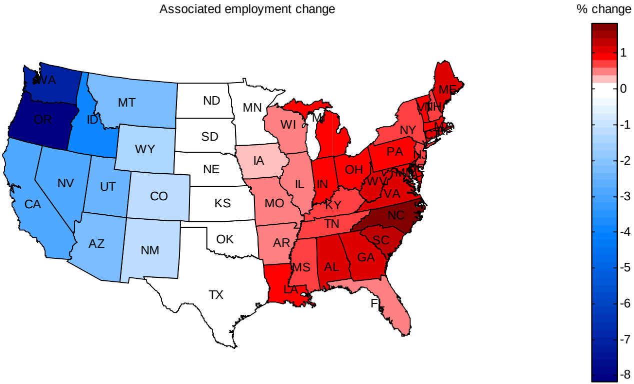
Multiplicity of equilibria - Agglomeration on West Coast



Multiplicity of equilibria- Agglomeration on East Coast



Multiplicity of equilibria- Agglomeration on East Coast



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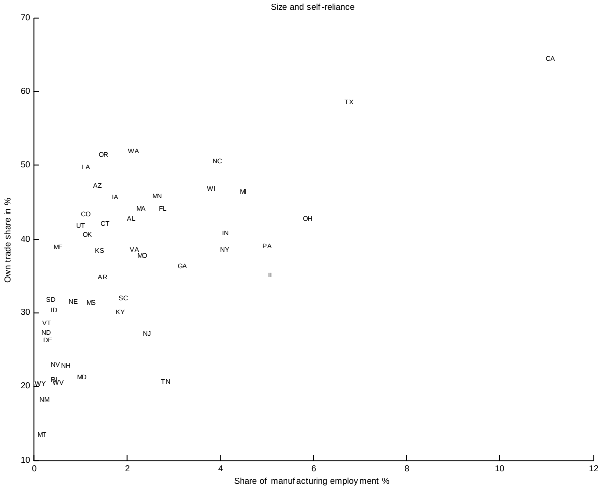
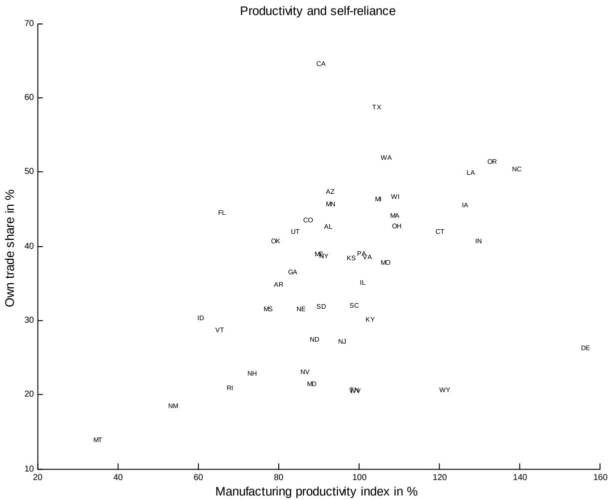
Optimal subsidies - Determinants of own trade share



Optimal subsidies - Determinants of own trade share



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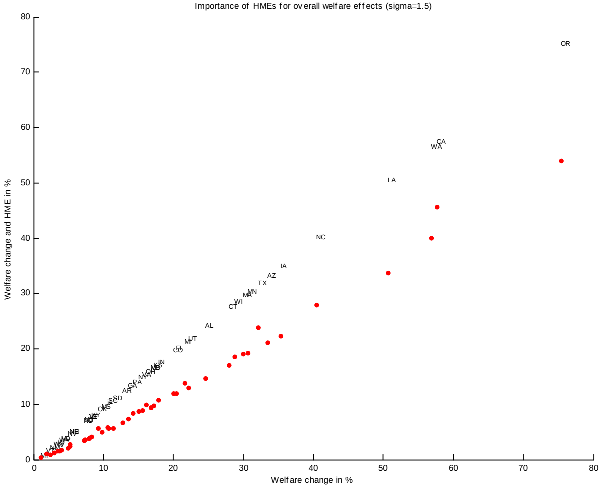
Optimal subsidies - Decomposition of welfare effects



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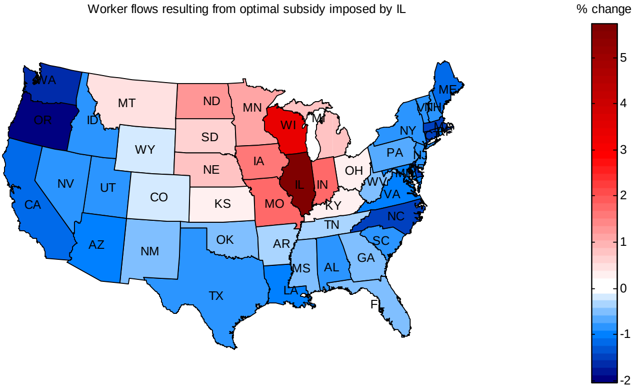
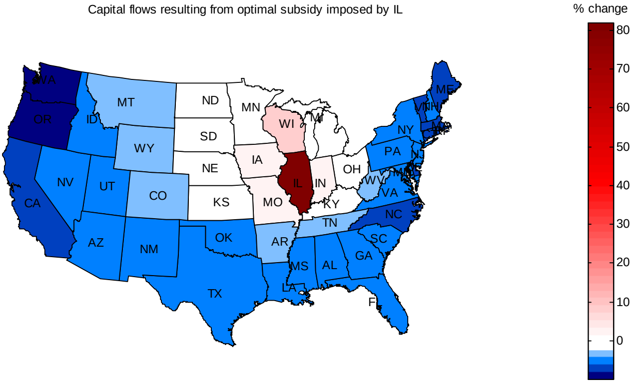
Optimal subsidies IL - Geography of labor reallocation



Optimal subsidies IL - Geography of capital reallocation



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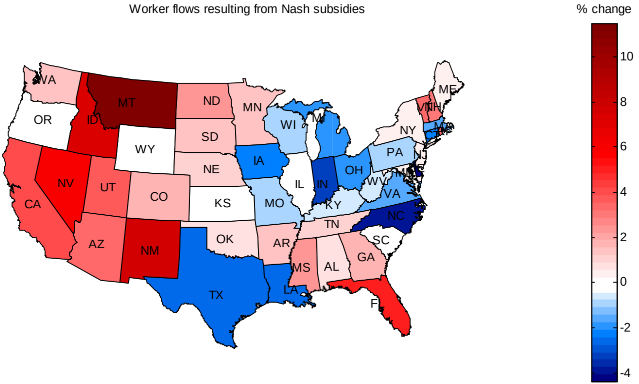
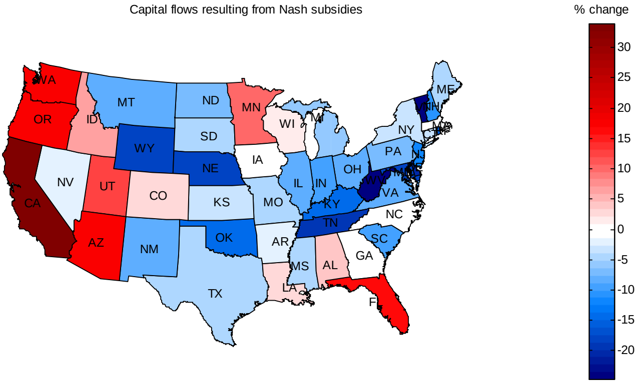
Nash subsidies - Geography of labor reallocation



Nash subsidies - Geography of capital reallocation



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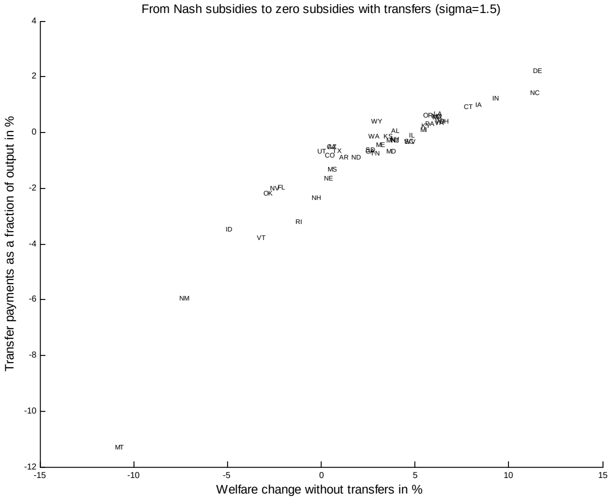
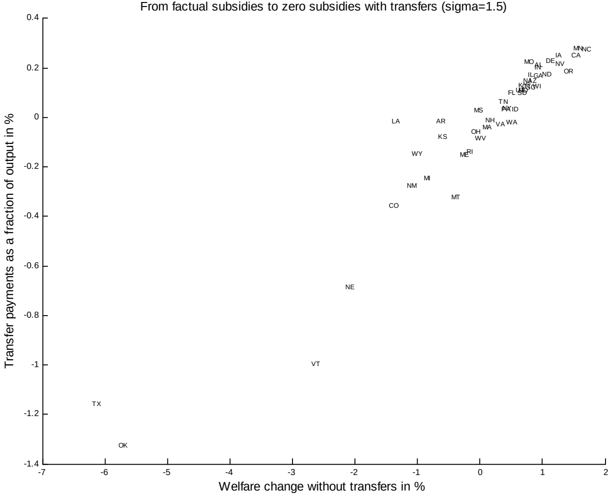
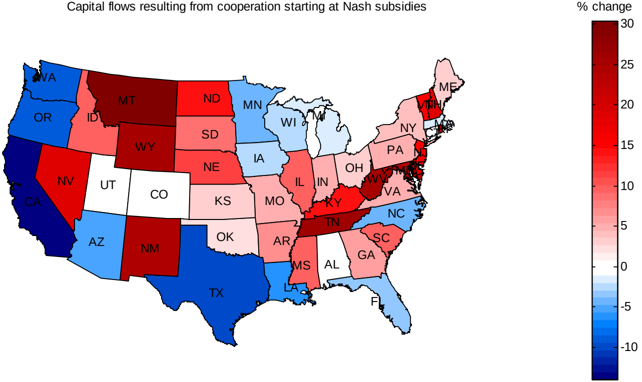
Cooperative subsidies - Transfers



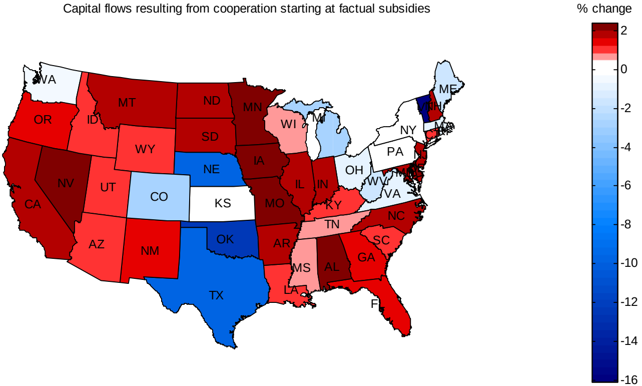
Cooperative subsidies - Transfers



Cooperative subsidies - Geography of capital reallocation



Cooperative subsidies - Geography of capital reallocation



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